United States
Department of
Agriculture

Forest
Service

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Management**

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INVENTORY OF BEECH BARK DISEASE MORTALITY AND DECLINE ON THE MONONGAHELA NATIONAL FOREST, WEST VIRGINIA

Report No. 84-4

3400
March 1984

INVENTORY OF BEECH BARK DISEASE MORTALITY AND DECLINE ON THE MONONGAHELA NATIONAL FOREST, WEST VIRGINIA

by

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ABSTRACT

Color-IR aerial photography, as part of a multistage sampling system was used to estimate actual and potential losses due to beech bark disease in West Virginia. Dead, dying and chlorotic beech were readily discerned on the photography and separated from other vegetation damage. There were a total of 11,922 symptomatic trees (dead, dying, or acutely chlorotic) on 17,986 acres, representing a total net volume of 319,512 ft^3 or 1,254,981 board feet and 2,208 cords on the Monongahela National Forest and intermingled private lands.

INTRODUCTION

Beech bark disease is a tree killing disease complex of American beech, Fagus grandifolia Ehrh., and European beech F. sylvatica L. The complex involves a scale insect, the beech scale, Cryptococcus fagisuga Lind., and Ascomycete fungi, in the genus Nectria (Ehrlich 1934, Cotter and Blanchard 1981, Houston and O'Brien 1983).

The beech scale is spread primariy by wind in late summer and fall during the crawler stage. Patterns of infestations on individual trees vary considerably. Tree bark is initially colonized in protected areas underneath branches, in fissures and wounds, and among lichens and mosses. The insect population builds to such high levels that much of the bole can be infested (Fig. 1). The bark is altered in a way that allows the Nectria fungi to invade and kill patches of bark and cambium. These necrotic areas may coalesce to girdle and kill the tree (Fig. 2).

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Figure 1 - American beech with heavy bole infestation of beech scale, Cryptococcus fagisuga Lind.

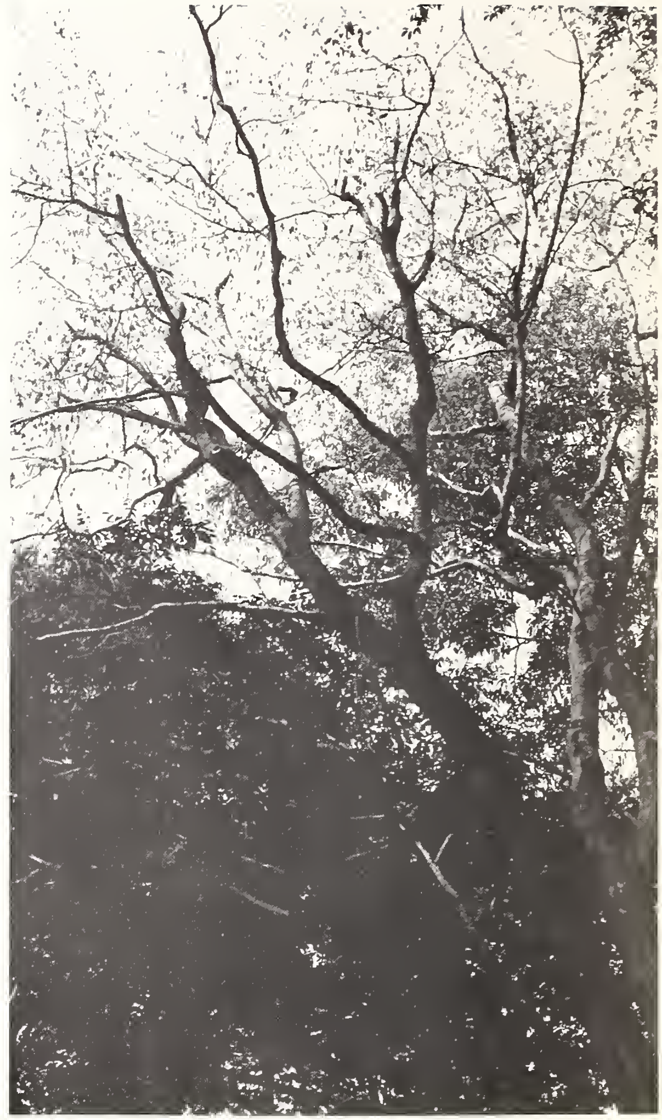

Figure 2 - American beech dying from beech bark disease, Shavers Mountain, Monongahela National Forest, West Virginia.

As scale populations begin to build and trees subsequently become infected by Nectria, leaves often become chlorotic, small and sparse. Trees with weak, thin crowns may persist for several years before they die. Sometimes trees die even before these foliar symptoms appear (Houston et al. 1979). The current year's dead leaves can be retained for some time once a tree is killed. Frequently, tree crowns are partially killed and/or the bole breaks resulting in a phenomenon known as "beech snap".

The beech scale was introduced from Europe into North America in 1890 near Halifax, Nova Scotia, Canada, and has since spread southward and westward. Disease development in northeastern forests has been characterized into three arbitrary stages (Shigo 1972). The "advancing front" is described by a building population of scale insects; the "killing front" by large numbers of scale insects, severe attacks by Nectria and resultant tree mortality; and the "aftermath zone" by old, often defective trees, young defective sprout thickets, and an endemic population of scale and Nectria (Shigo 1972; Houston 1975). This pattern has been observed throughout the northern hardwood forest extending into northeastern Pennsylvania (PA Dept. of Env. Res. 1983).

In forests of northern New England affected by beech bark disease, mortality of beech averages 85 percent (Houston et al. 1979). It takes an average of three years for a beech to die once foliar symptoms are visible (D. Houston, NEFES, personal communication, 1983).

Beech bark disease was discovered in West Virginia in 1981, approximately 300 air miles from the previous known range of beech scale (Mielke et al. 1982). Subsequent surveys have established the presence of the scale on over 100,000 acres of northern hardwood forest on the Monongahela National Forest, on a small portion of the George Washington National Forest in Virginia, and on intermingled private lands (Fig. 3). The killing front is concentrated in the south and the advancing front fans out to the north and east over the range of the infestation. Based on the presence of these stages of disease development, the scale probably arrived in West Virginia over 25 years ago (D. Houston, NEFES, personal communication 1983). Exactly how and where the scale was introduced into West Virginia is presently unknown.

In 1983 a special survey was conducted to inventory the status of beech bark disease in West Virginia. The objectives of this survey were to evaluate the suitability of using large format color-infrared aerial photography as part of a multistage sampling system to determine the area affected, assess the damage caused by beech bark disease, and estimate the potential impact as represented by non-symptomatic beech trees present throughout the area infected by beech bark disease.

METHODS

DESCRIPTION OF TEST SITE

Approximately 50,000 acres of the Greenbrier Ranger District, Monongahela National Forest, and intermingled private lands in Pocohontas and Randolph Counties, West Virginia, were surveyed.

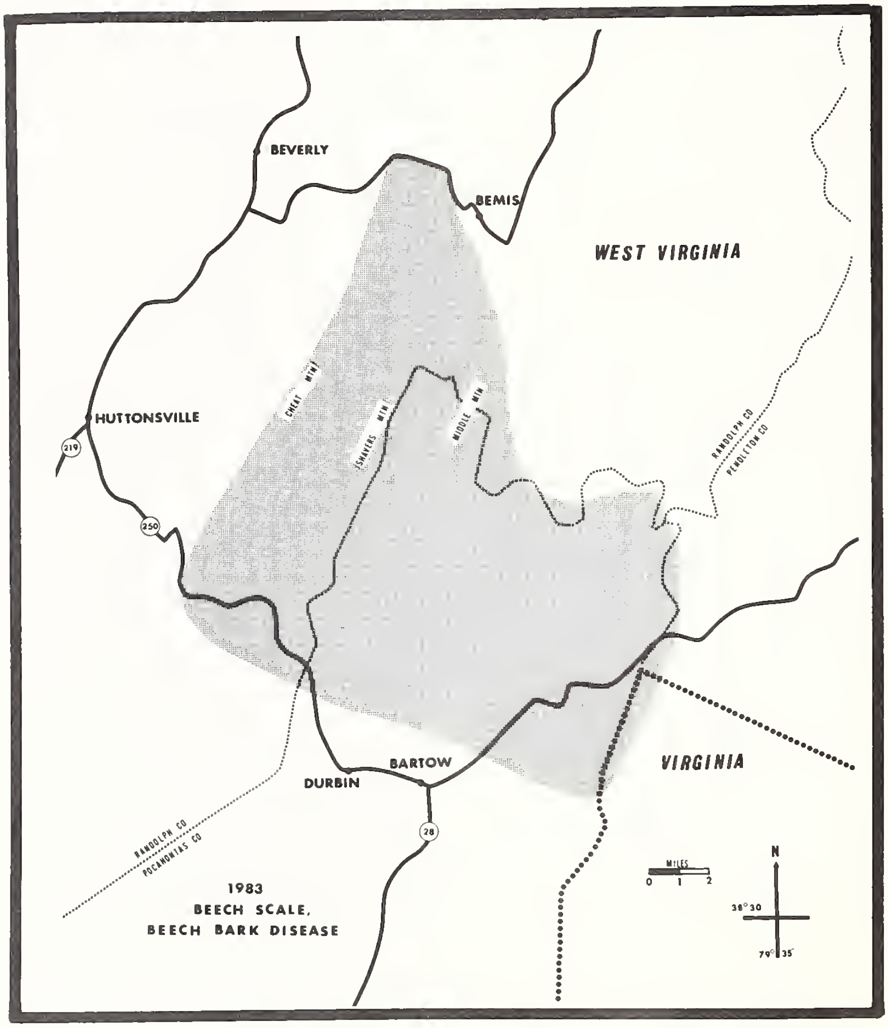

Figure 3 - Known distribution of beech scale in Virginia and West Virginia.

The survey area encompassed portions of two physiographic provinces; the Allegheny Mountains and the Ridge and Valley system, with elevations ranging from 3,000 to 4,200 feet. Forest cover type consists predominantly of Allegheny hardwoods, a mixture of yellow birch, *Betula alleghaniensis* Britt., American beech, *Fagus americana* L., sugar maple, *Acer saccharum* Marsh., red maple, *A. rubrum* L., black cherry, *Prunus serotina* Ehrh., and white ash, *Fraxinus americana* L. Red spruce, *Picea rubens* Sarg., predominates at the highest elevations. A mixture of eastern white pine, *Pinus strobus* L., eastern hemlock, *Tsuga canadensis* (L.) Carr., various oaks, *Quercus* spp., black locust, *Robinia pseudoacacia* L., yellow poplar, *Liriodendron tulipifera* L., and other hardwoods occur at lower elevations and on south facing slopes.

A variety of other forest pest problems are present in the area whose damage could be confused with symptoms of beech bark disease on aerial photographs. There is widespread mortality of red spruce from a not as yet known cause. A complex of spring hardwood defoliators are present in the area. These include the half-wing geometer, *Phigalea titea* Cram., the linden looper, *Erannis tiliaria* Harr., fall cankerworm, *Alsophila pometaria* Harr., forest tent caterpillar, *Malacosoma disstria* Hbn., cherry scallop shell moth, *Hydria prunivorata* Ferguson, oak leaf tier, *Croesia semipurpurana* Kearfott, and the fruit tree leaf roller, *Archips semiferanus* Walker. However, if these insects caused damage in the survey area, refoliation would have occurred by the time of the survey. Active infestations of locust leaf miner, *Odontota dorsalis* Thunb., were present on black locust as were infestations of fall webworm, *Hyphantria cunea* Drury, on a variety of hardwoods. There are a number of standing dead American chestnut, *Castanea dentata* Marsh, Borkh., killed by chestnut blight, *Endothia parasitica* Murr., P.J. & H.W. And., 30-40 years ago. In addition, *Nectria galligena* Bres., is causing severe cankering and mortality of yellow birch. A full complement of root and stem diseases is also present.

PHOTOGRAPHIC PARAMETERS

Five blocks, ranging from 8 to 25 square miles, were included in the survey. These were selected on the basis of an earlier aerial sketchmap survey designed to locate concentrations of hardwood decline and mortality suspected to be caused by beech bark disease (Fig. 4).

An aerial photo mission was flown August 14 and 15, 1983, using a Forest Service Beechcraft Queen Air[2/] aircraft equipped with a Zeiss RMK 21/23 9-inch format camera with an 8-1/4 inch focal length lens. Blocks and flight lines were marked on USGS 7-1/2 minute topographic maps to aid in locating flight lines and navigating visually along each line. All blocks were flown at 60% overlap and 20% sidelap at a planned scale of 1:6,000. Kodak Aerochrome infrared film (Type 2443) in combination with a Wratten 12 (minus blue) and antivignetting filters was used for the mission. Color-IR film was selected because of its ability to penetrate atmospheric haze and provide ready separation of conifers from hardwoods.

[2/]Mention of commercial products is for convenience only and does not imply endorsement by USDA Forest Service.

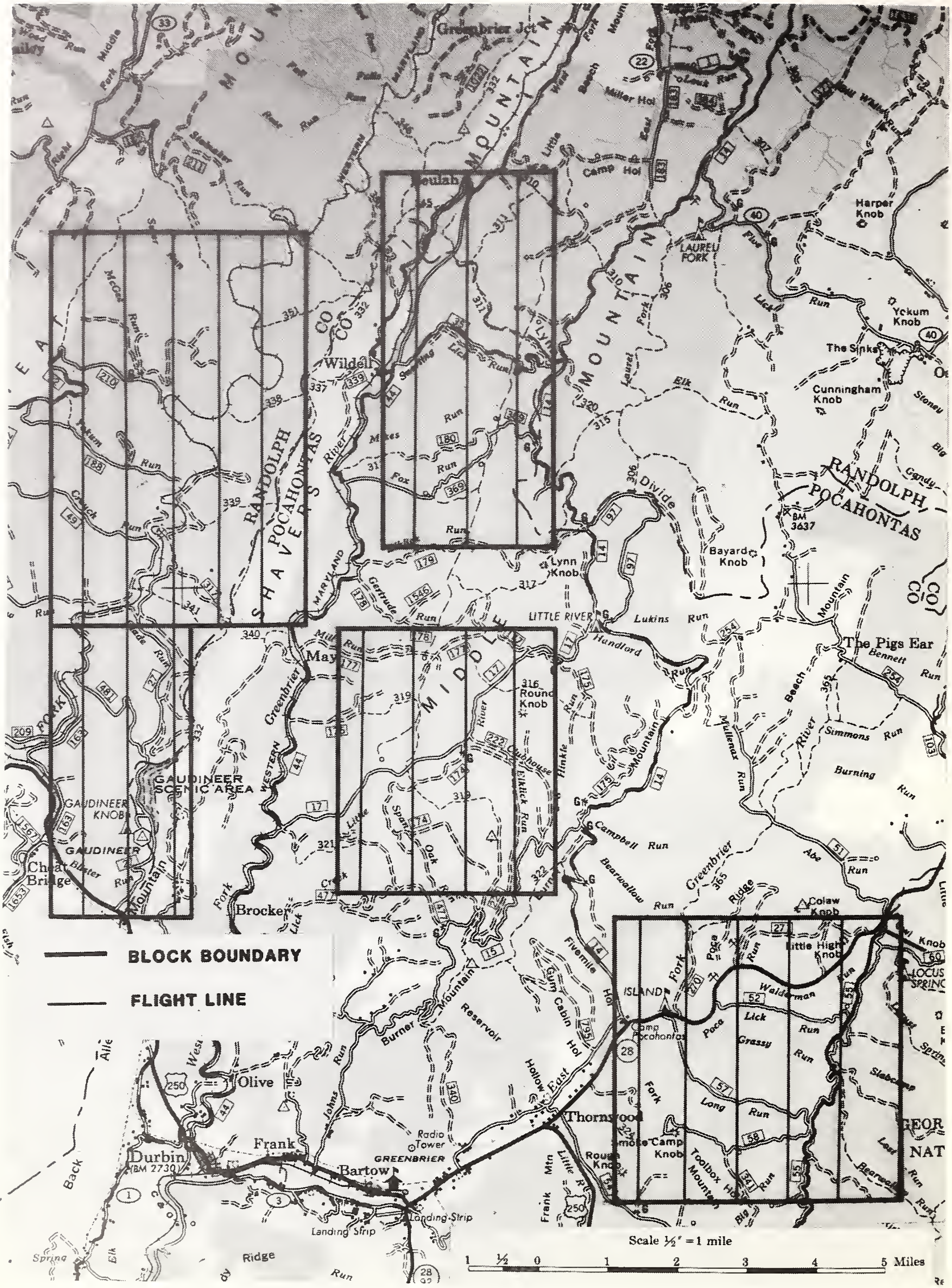

Figure 4 - Areas of the Monongahela National Forest and adjoining private lands in West Virginia included in inventory of beech bark disease, August 1983.

In addition, a test strip was flown over one block at a planned photo scale of 1:4,000. This consisted of a single flight line photographed in both color transparency film (Ektachrome EF SO-397), and color-IR film. The test strip served as a means of comparing damage symptoms as they appear on color-IR film with what can be seen with the naked eye or on normal color film.

PHOTO INTERPRETATION

STRATIFICATION AND MAP TRANSFER - The forested area within each block was stratified to identify concentrations of dead and dying hardwoods and eliminate stands of pure or nearly pure red spruce. A single stratum, areas with approximately one or more dead, dying or chlorotic hardwoods per acre was defined. Boundary of areas meeting this criterium was inked directly on the photos. These were transferred to a 7-1/2 minute USGS map base by sketchmapping. Total area of this stratum was measured from the map base with an electronic planimeter.

PLOT SELECTION AND TREE COUNTS - Photo plots were established by selecting every fourth photo on each flight line. If the photo contained no stratified stands, it was discarded. If areas with one or more dead, dying or declining hardwoods per acre appeared on the photo, a 40 acre plot was established either at the principle point or a point close to the principle point where a plot could be established entirely within a stratified stand. Forty-one photo plots were located in this manner.

Scale of each photo containing a plot was determined and a clear plastic grid overlay of the appropriate scale, subdivided into 16-2.5 acre subplots, was superimposed over the photo at plot center.

Prior to actual photo interpretation, several sites of suspected beech bark disease and other vegetation damage, e.g., mortality of red spruce, defoliation by locust leaf miner, etc., were classified on aerial photos and visited on the ground. These observations provided the basis for developing a classification system used for photo interpretation and for training interpreters.

Photo interpreters were trained to recognize dead, dying, and chlorotic trees on color-IR photos by simultaneously viewing and classifying tree crowns on several 2.5 acre subplots in stereo with a pair of Old Delft scanning stereoscopes at 4.5X magnification (Fig. 5). When all photo interpreters were confident they could consistently classify crown condition as "healthy, acutely chlorotic, dying and dead," they made counts of dead, dying and acutely chlorotic trees on each of the 2.5 acre subplots per photo plot.

GROUND DATA ACQUISITION - Following photo interpretation, ground plots (secondary sampling units), were selected using the probability proportional to size (PPS) method developed for inventory of tree mortality caused by mountain pine beetle, <u>Dendroctonus</u> <u>ponderosae</u> Hopk. (White et al. 1983). Twenty-four, 2.5-acre ground plots (2 from each of 12 photo plots also selected using PPS) were precisely located on the ground using the positive photo transparancies and topographic maps. Data were collected during the period September 7-16, 1983. Dbh of all dead and acutely chlorotic beech larger than 5 inches dbh was recorded. Within each 2.5-acre plot, four variable prism points (BAF=10 ft^2) were randomly located and dbh of all remaining beech greater than 5-inches was recorded.

Figure 5 - Photo interpreters simultaneously viewing tree crowns on color-IR photos with a pair of Old Delft stereoscopes.

DATA ANALYSIS - Data were analyzed according to procedures described by White et al. (1983). This provided estimates of area, numbers of trees and volume affected in accordance with National standards described in the Forest Insect and Disease Information System (FIDIS) (Ciesla and Yasinski 1980).

RESULTS

PHOTO QUALITY

Photo quality was good to excellent. Despite considerable turbulence and scattered cloud cover, the area, with the exception of part of one block, was effectively covered. Color balance was well within acceptable limits despite the presence of a heavy layer of atmospheric haze, typical of midsummer in the Appalachians. Actual photo scale ranged from 1:5,200 to 1:7,600.

APPEARANCE OF VEGETATION DAMAGE

Vegetation exhibited a wide range of colors on the photographs. This was in part due to the great variety of tree species present and the presence of beech bark disease symptoms. In addition, a considerable volume of red spruce mortality was present as were several mid-to-late summer hardwood defoliators, including locust leaf miner on black locust, cherry scallop shell moth on black cherry, and fall webworm on several species of hardwoods.

A wide range of damage symptoms, including chlorosis, and dead and dying trees that are associated with beech bark disease centers appeared on the photos. Chlorotic beech ranged in crown color from pink to white on color-IR film. Dying trees with brown dessicated foliage appeared yellow. Dead trees with no foliage appeared as bare crowns with a dendritic branch pattern. It was the presence of all of these symptoms in a stand that indicated beech bark disease (Figs. 6, 7).

A dichotomous key (Table 1) was developed to describe how crown conditions indicative of beech bark disease were separated from healthy vegetation or other vegetation damage. Only dead, dying and acutely chlorotic trees were included in the photo counts.

ESTIMATES OF LOSS

Mortality and decline caused by beech bark disease occurred over 17,986 acres. A total of 11,922 trees were affected, representing a net volume of 319,512 ft^3 (S.E. $\pm$ 30.90 percent), or 1,254,981 board feet International 1/4 (S.E. $\pm$ 33.74 percent) and 2,208 cords (S.E. $\pm$ 33.89 percent) (Table 2).

Remaining live beech volume per acre or potential mortality, over the affected area was 791 ft^3, or 2,411 board feet and 3.02 cords (Table 3). In localized areas where the proportion of American beech is considerably higher, greater per acre tree mortality and volume losses can be expected (Mielke and Houston 1983).

DISCUSSION

Color-IR aerial photography, as part of a multistage sampling system is an effective means of estimating levels of tree mortality and decline caused by beech bark disease. Because known areas of beech bark disease were not photographed, overall tree loss was underestimated. Photo interpretation was made more difficult due to the presence of other pest damage and tree mortality, however this was accounted for in the ground surveys and data analysis.

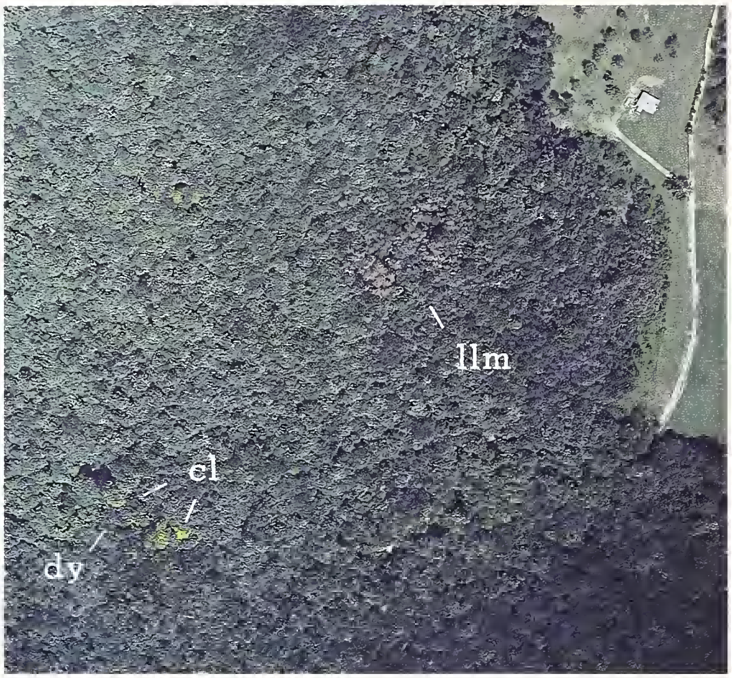

Figure 6 - Above, color (SO-397) aerial photo of hardwood forest on the Monongahela National Forest, West Virginia. Chlorotic trees (cl) and dying trees (dy) are American beech infected with beech bark disease. Discolored trees near photo center (llm) are black locust infested by locust leaf miner. Scale = 1:4,000. Below, color-IR (2443) photo approximately the same area. Scale = 1:6,000.

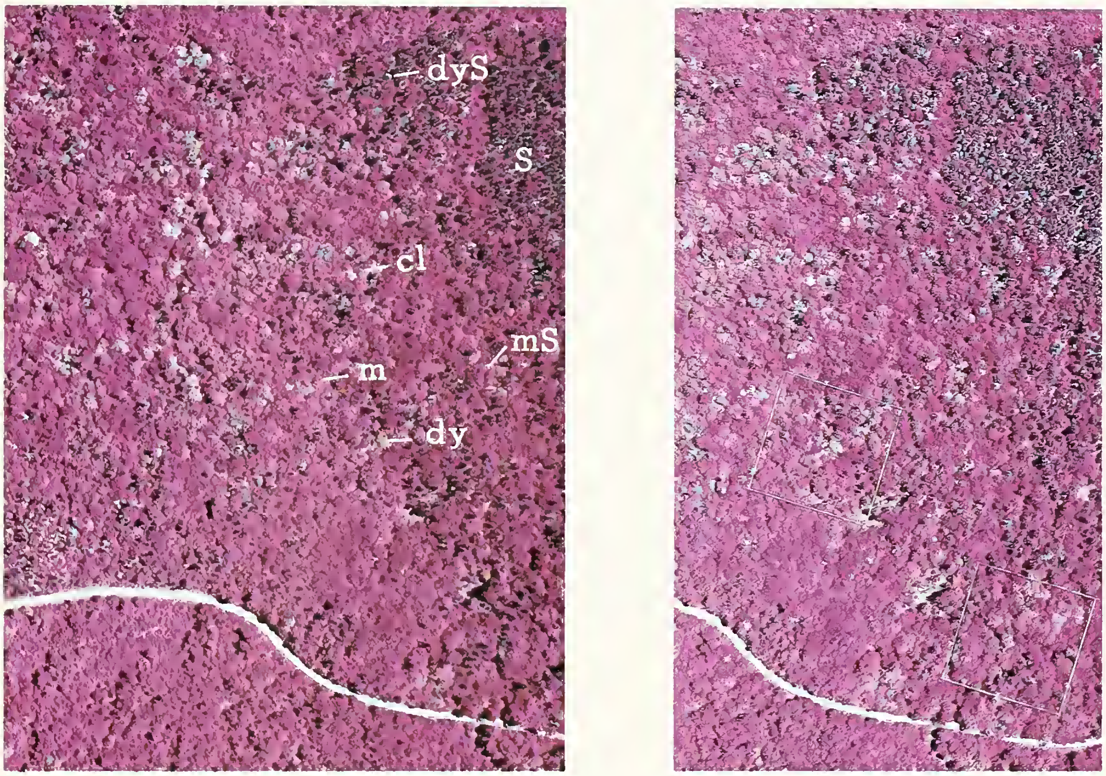

Figure 7 - Color-IR (2443) stereogram of forested area on the Monongahela National Forest, West Virginia, showing beech trees in various stages of decline due to beech bark disease; acutely chlorotic (cl), dying (dy), and dead (m). Darker red brown crowns are red spruce (s). A dying spruce (dyS) and a group of dead spruce (mS) are also shown. Squares on right photo represent 2½ acre ground plots. Scale = 1:6,000.

Table 1 - Dichotomous key to aid in classification of crown condition on color-IR photos in areas affected by beech bark disease, Monongahela National Forest, West Virginia.[1]

1.	Crown with little or no foliage, bare branches visible	2
1a.	Crown with foliage	3
2.	Branch pattern dendritic, color light gray (190 l.b. gray, 264 l. gray)	Dead hardwood[2]
2a.	Branches radiating from a central mainstem, color white or light gray (263 white, 264 l.gray, 190 l.b. gray) .	Dead red spruce
3.	Foliage color red, magenta, red brown or biege	4
3a.	Folige color pink, yellow, or white.	5
4.	Crown shape rounded, foliage color red, magenta, or light reddish brown (living hardwood vegetation)	6
4a.	Crown shape spirelike, foliage color red brown (40 s.r. br. or 16 d. red) or light red brown near sunspot (42 l.r. br.)	Living red spruce
5.	Crown color yellow or olive green yellow	7
5a.	Crown color white or pink.	8
6.	Foliage color light reddish brown (42 l. gy. r. br. or 45 l. gy. r. br.) Foliage fine textured	Leaf mining of black locust by locust leaf miner
6a.	Foliage color red or magenta (3 deep pink, 12 s. red 28 d.p. pk. or 251 d.p. pk.)	Living Hardwood
7.	Crown shape rounded, foliage color yellow (82 v. yellow or 83 brill. yellow)	Dying hardwood[2]
7a.	Crown shape spirelike color yellow or green yellow (109 l. gy. ol. or 112 l. ol. gray).	Dying red spruce
8.	Foliage color pink (41 pink or 5 m. pink). . .	Slightly chlorotic hardwood
8a.	Foliage color white or light pink (263 white or 9 pk. white).	Acutely chlorotic hardwood[2]

[1] Notations in parenthesis refer to designation on National Bureau of Standards ISCC-NBS color chips which accompany the Manual of Color Aerial Photography (Smith and Anson 1968). They are provided for a general description of foliage color. Actual foliage color may vary slightly.

[2] Crowns classified into those categories were included in photo count.

Table 2 - Status of beech bark disease on American beech on the Monongahela National Forest and adjoining private lands in West Virginia, 1983[1]

Acres of Infection	Number of Trees	Cubic Foot Volume	Merchantable Volume Board Ft[2]	Merchantable Volume Cords
17,986.1	11,921.7	319,511.7	1,254,981.26	2,208.4
Standard Error (%)	19.67	30.90	33.74	33.89

[1]Derived from: Total Net Volume of Growing Stock, Monongahela National Forest, 1981 Remeasurement of Permanent Inventory Plots.

[2]International 1/4, estimated to a variable top diameter not less than 9.0 inches.

Varying degrees of chlorosis in beech exhibited varying hues of pink to white. We elected to count only acutely chlorotic trees, those appearing as white or nearly white. This may have resulted in omission errors which were further exacerbated by a several week delay between the time when the photography was acquired and when ground plots were sampled. Some slightly chlorotic trees may have become more chlorotic during this period and therefore would have been counted on the ground plots but not on the photo plots. Overall, these errors probably resulted in a conservative estimate of dead and dying trees and increased the size of the sampling error.

Aerial and ground data were acquired in sufficient time to avoid the confounding effect of fall coloration of hardwoods. However, when planning future surveys to estimate beech bark disease decline and mortality, the effect of early fall coloration of hardwood foliage at the higher elevations must be considered.

ACKNOWLEDGMENTS

We thank the following individuals for their participation in this work:

Ron Bell, Pilot, USDA Forest Service, Region 2, Denver, Colorado.

Frank Kenney and Lynda Liptrap, USDA Forest Service, Forest Pest Management, Morgantown Field Office, for photo annotation, scale determination, photo interpretation and ground sampling.

Bob Acciavatti, Charles Engle, and Brad Onken, USDA Forest Service, Forest Pest Management, Morgantown Field Office, for ground sampling.

Clark Haynes, West Virginia Department of Agriculture, Plant Pest Control; Ben Miller and Dave Stack, USDA Forest Service, Monongahela National Forest, Greenbrier Ranger District, for assistance in ground sampling.

Table 3 - Stand table for live beech in infected area (10 ft^2 BAF, 96 plots)

Diameter Class	Number of Trees Tallied	Ft^2 BA/ Acre	Trees/ Acre	Ft^3/ Tree	Ft^3 Vol/ Acre	Bd Ft Vol/Tree	Bd Ft Vol/Acre	Cordwood Vol/Tree	Cordwood Vol/Acre
6	25	2.6	13.3	7.73	102.8	0	0	.060	.798
8	23	2.3	6.6	7.73	51.0	0	0	.060	.396
10	23	2.3	4.2	7.73	32.5	0	0	.060	.252
12	35	3.6	4.6	24.92	114.6	84.15	387.1	.066	.306
14	48	5.0	4.7	24.92	117.1	84.15	395.5	.101	.474
16	34	3.5	2.5	46.14	115.4	196.45	491.1	.048	.119
18	32	3.3	1.9	46.14	87.7	196.45	373.3	.155	.295
20	31	3.2	1.5	46.14	69.2	196.45	294.7	.202	.303
22	24	2.5	.9	90.24	81.2	419.42	377.5	.065	.058
24	4	.4	.1	90.24	9.0	419.42	41.9	.014	.001
26	4	.4	.1	90.24	9.0	419.42	41.9	.050	.005
30	1	.1	.02	90.24	1.8	419.42	8.4	.385	.008
Average 14.6									
Totals	284	29.2	40.4		791.3		2411.4		3.02

Dave Houston, USDA, NEFES; Harry Mahoney, USDA, Forest Service, Monongahela National Forest; and William MacDonald, West Virginia University, for their constructive review of this manuscript.

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